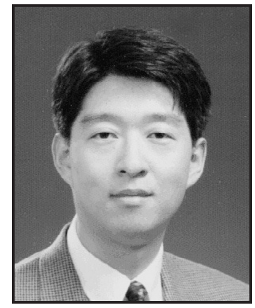
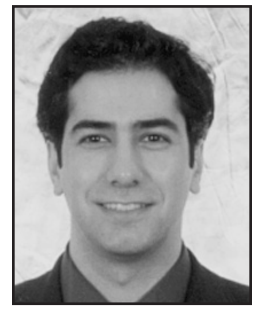
Session 21 Overview

Sensors and MEMS



Chair: Euisik Yoon, *University of Minnesota, Minneapolis, MN*



Associate Chair: Farrokh Ayazi, *Georgia Institute of Technology, Atlanta, GA*

A major challenge in integrated sensors and MEMS has been to enhance performance by integrating signal processing and conditioning circuitry with the sensor or MEMS in CMOS technology. The availability of submicron CMOS processes allows a significant amount of customized circuitry and DSP to be packaged with or embedded in sensors and MEMS. In addition, wireless links can be implemented for supplying power and transmitting data.

The eight papers in this session illustrate recent advances in microsensors and MEMS technologies that yield higher integration with CMOS circuitry for improved performance, smaller form factors, and lower cost implementations. Advanced micromachined devices are interfaced with CMOS electronics to achieve state-of-the-art performance and wireless data transfer. Novel CMOS-integrated circuit techniques are implemented for precision sensing of strain, angular velocity, magnetic field, mass change and single photons. The closed-loop control of MEMS resonators provides precision detection of changing mass and angular motion. A magnetic concentrator integrated on a CMOS chip paves the way to implementing a micro-compass on a chip.

The first paper of the session, 21.1 from Case Western Reserve U, presents a wireless sensing microsystem powered by an external RF power source for precision sensing of strain and temperature. The system can resolve sub-micro strain over a 10kHz bandwidth and simultaneously transmit strain and temperature data to an external receiver base. Paper 21.2 from Melexis describes a single-chip CMOS micro-compass with integrated DSP. The Hall-based microsensor uses a post-processed metal layer as a magnetic field concentrator to implement a three-axis magnetic field transducer. The micro-compass provides heading resolution of better than 0.5 degrees in a die area of $2.3\times2.8mm^2$. Paper 21.3 from CEA and Ecole Centrale presents a low-noise servo-controlled micro-fluxgate magnetometer with a programmable ASIC that makes the sensor adaptable for various applications.

Today, affordable MEMS gyroscopes do not have the resolution required for GPS-augmented navigation. Paper 21.4 from Georgia Tech describes a solution to this problem; a silicon-based tuning-fork gyroscope interfaced with a CMOS ASIC for dynamic tuning and control of the device achieves sub-deg/hr precision and accuracy. When combined with precision micro-accelerometers, these devices can assemble into micro inertial measurement units (micro-IMU) for short-range navigation in consumer products.

Paper 21.5 from Space Research Institute, Fraunhofer Institute, and European Research and Technology Centre presents a high dynamic range $\Delta\Sigma$ modulator interface for read-out of fluxgate sensors. The chip can resolve magnetic fields with a resolution of 10pT and shows radiation hardness for space applications. The authors of Paper 21.6 from Uresent another CMOS integrated micro-system for detecting the earth's magnetic field. An integrated micro-fluxgate sensor with a sputtered ferromagnetic core is interfaced with a CMOS ASIC to achieve 4° accuracy on measured angles while providing a digital output.

Paper 21.7 from TU Munich, Infineon Technologies, Siemens, and Qimonda presents an FBAR-based gravimetric sensing array for operation in liquids. The resonant FBAR array is flip-chip bonded to CMOS circuits to create high-frequency oscillator arrays with picogram mass sensitivity. Finally, Paper 21.8 from EPFL presents a CMOS single-photon avalanche diode (SPAD) detector array with high-speed readout functionality for molecular imaging applications.

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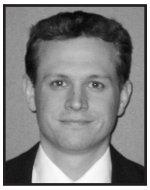
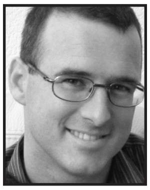


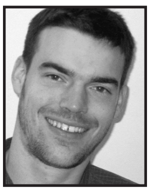
21.1 A Wireless Strain Sensing Microsystem with External RF Power Source and Two-Channel Data Telemetry Capability
M. Suster, Case Western Reserve University, Cleveland, OH **8:30 AM**

A wireless strain sensing microsystem is powered by a 50MHz signal and can simultaneously telemeter both digitized strain and temperature data over the RF powering link using passive PSK and ASK modulations, respectively. The prototype system achieves a minimum detectable strain of 0.87$\mu\varepsilon$ over a 10kHz bandwidth with a maximum input signal of ±1000$\mu\varepsilon$. The temperature sensor resolution is 0.02$C°_{rms}$ with a 100Hz BW. The chip is fabricated in 1.5μm CMOS and dissipates 6mW.



21.2 A CMOS Single-Chip Electronic Compass with Microcontroller **9:00 AM**
C. Schott, Melexis, Bevaix, Switzerland

A CMOS single-chip electronic compass with a 16b DSP for heading calculation is presented. A Hall-based 3-axis magnetic-field sensor and analog amplifiers, with a gain of up to 20,000, drive a 12b ADC. A 0.35μm low-voltage CMOS process is used with an added metal layer working as a magnetic-field concentrator with a gain of about 6 to 10. The chip works with a 2.2 to 3.6V supply and draws 5mA in normal mode. The heading resolution is better than 0.5° and the accuracy is better than ±2°.



21.3 A 100Hz 5nT/√Hz Low-Pass $\Delta\Sigma$ Servo-Controlled Microfluxgate Magnetometer Using Pulsed Excitation **9:30 AM**
E. Colinet, CEA-LETI, Grenoble, France

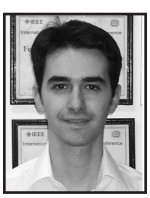
An ASIC for an integrated microfluxgate sensor uses pulsed excitation, a 2^{nd}-order $\Delta\Sigma$ modulator, an LPF and an FIR DAC current generator in a fully-digital field-canceling loop to achieve high linearity over a 120μT DR. A low noise floor of 5nT/√Hz is measured over a 100Hz BW. This ASIC can be adapted to numerous applications since it is fully programmable. The 9mm^2 ASIC consumes 36mW from 3.3V and is fabricated in a 0.35μm CMOS process.

21.4 A 0.2°/hr Micro-Gyroscope with Automatic CMOS Mode Matching **10:15 AM**
A. Sharma, Georgia Institute of Technology, Atlanta, GA

A 3V CMOS IC and interface architecture for automatic mode matching of a high-Q silicon tuning-fork gyroscope is presented. Using this scheme, the frequencies of the drive and sense resonant modes of the gyroscope are automatically matched to yield an effective Q of 36,000 in the sense mode. The angular rate sensor yields a bias drift of 0.2°/hr and a scale factor of 88mV/°/s. The IC consumes 6mW and has an area of 2.25 mm^2.

21.5 A 92dB-DR 13mW $\Delta\Sigma$ Modulator for Spaceborn Fluxgate Sensors **10:45 AM**
M. Oberst, Fraunhofer Institute for Integrated Circuits, Erlangen, Germany

A 2-2 cascaded $\Delta\Sigma$ modulator is adapted for near sensor digitization of the magnetic field measured by a fluxgate sensor. The chip contains three fluxgate channels (13mW each) and one voltage channel (10mW). The fluxgate channels achieve a DR of 92dB for field ranges greater than ±2,000nT with 10pT resolution. The chip operates up to 260krad of total ionizing dose. The chip uses 20mm^2 in a 0.35μm CMOS process.



21.6 A CMOS 2D Microfluxgate Earth Magnetic Field Sensor with Digital Output **11:15 AM**
A. Rossini, University of Pavia, Pavia, Italy

A complete CMOS integrated microsystem for detecting the direction of the Earth's magnetic field (whose full-scale value is on the order of 60μT), realized with the micromodule approach, including both sensor and electronic interface circuit, achieves 4° accuracy on the measured angle and provides a digital output. The system response is linear in the range of ±60μT, with a maximum non-linearity error of about 3% of full-scale.

21.7 An Integrated Gravimetric FBAR Circuit for Operation in Liquids Using a Flip-Chip Extended 0.13µm CMOS Technology **11:30 AM**
R. Thewes, Qimonda, Munich, Germany

A 0.13μm CMOS chip is fabricated with eight resonator-amplifiers to demonstrate a highly integrated gravimetric sensor based on an FBAR oscillator. The oscillator is attached via flip-chip bonding to a CMOS resonator. Each active 1.86GHz oscillator draws 27mA from a single 1.7V supply for 200×200μm^2 sensors. The resonance frequency shifts by 5MHz in ethanol and 7.3MHz in water and jitter is <3kHz.

21.8 A 128×2 CMOS Single-Photon Streak Camera with Timing-Preserving Latchless Pipeline Readout **11:45 AM**
E. Charbon, EPFL, Lausanne, Switzerland

A 0.35μm CMOS camera uses 128 single-photon avalanche diodes to simultaneously detect 128 photon times-of-arrival, which are then translated onto pulses that are independently injected into a timing-preserving delay line, implemented along the sensor's column. With this design, an overall timing accuracy of 145ps (worst case) is achieved, which enables high-precision time-correlated single-photon counting for state-of-the-art physics, bio-molecular, and medical imaging applications.